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TITLE: TRAC-PF1 POSTTEST PREDICTIONS FOR THE SEMISCALE NATURAL-CIRCULATION TESTS S-NC-2 and S-NC-6

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TRAC-PF1 POSTTEST PREDICTIONS FOR THE SEMISCALE NATURAL-CIRCULATION TESTS S-NC-2 AND S-NC-6

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ABSTRACT

The Transient Reactor Analysis Code (TRAC) being developed at the Los Alamos National Laboratory under the sponsorship of the Reactor Safety Research Division of the US Nuclear Regulatory Commission is an advanced, best-estimate systems code to analyze light-water-reactor accidents. TRAC-PF1 is the most recent publicly released version of TRAC.

In this paper we compare the TRAC predictions to the data for the Semiscale natural-circulation Tests S-NC-2B and S-NC-6. S-NC-2B is a baseline test covering single- and two-phase natural circulation as well as reflux; here, TRAC compares quite well with the experiment results for mass flow. For Test S-NC-6, which is a reflux test with various amounts of nitrogen injected into the system, the TRAC prediction of the reflux rate is close to the experiment value with no nitrogen in the system. Ultimately, the maximum reflux rate predicted by TRAC is about 20% higher than the data.

INTRODUCTION

In this paper, we assess the capability of the PF1 version of the Transient Reactor Analysis Code, TRAC, to make accurate posttest predictions for the Semiscale natural-circulation tests, S-NC-2B and S-NC-6. These experiments consider single-phase natural circulation, two-phase natural circulation, and reflux, all of which are important heat removal mechanisms for a large class of postulated pressurized water reactor accidents. We have included a brief description of the

TRAC input models, comparisons between the TRAC predictions and the experiment data, and a concise analysis of our results.

FACILITY AND EXPERIMENT DESCRIPTION

One of the purposes of these tests is to provide a natural-circulation and reflux data base for the assessment of best-estimate codes. The tests considered in this paper, S-NC-2B and S-NC-6, cover the broad spectrum of the tests. S-NC-2B is a baseline test covering three core power levels and several system inventories; single-phase natural circulation, two-phase natural circulation, and reflux are observed. S-NC-6 is a reflux test with various amounts of a nitrogen gas injected into the hot leg of the system. In all these tests, only an abridged version of the Semiscale facility is used.

For Test S-NC-2B only the intact loop and the vessel are used. The intact-loop pump is replaced by an orificed spool piece to avoid uncontrolled primary fluid loss through the leaky pump;[1] the orifice does not block the lower half of the pipe.[2] The upper head of the vessel is removed to avoid nonuniform heating of the entire system and to avoid condensation on upper head structures.[1] The test is run as follows. The core power is stabilized at approximately 30 kW. Data is taken for the 100% inventory condition. Some liquid is drained from the lower plenum and measurements are taken when the system stabilizes. Measurements then are taken for various system inventories. The core power is stabilized at about 60 kW and the system is refilled to 100% inventory. Measurements are taken again at various inventories. The process is repeated for a core power of 100 kW.

In Test S-NC-6, the system is configured as in Test S-NC-2B except that provision is made for nitrogen to be injected just below the steam-generator inlet plenum. Because this is a reflux test, measurement techniques not used in S-NC-2B are employed to measure the reflux rate; a reflux meter is attached to the steam-generator inlet piping. This meter consists of a tee in the primary piping with a weld bead around the inside circumference and a standpipe for collecting and measuring the refluxed fluid.[3] To offset this net loss of liquid from the system, make-up water is injected into the lower plenum. The core power is maintained at a nominal 30 kW. Measurements are taken for no nitrogen in the system and then for increasing injected amounts of nitrogen.

During both tests, the pressurizer is used to establish the initial steady state for each core power level. It is valved out of the system before measurements are taken and before any drains of the system inventory. Further, in none of these tests is there a requirement for emergency core cooling water.

TRAC MODEL

The TRAC nodalization for S-NC-2B, as shown in Fig. 1, is uncomplicated reflecting the simplicity of the abridged Semiscale facility. However, there are some aspects that should be noted.

The TRAC-PF1 one-dimensional CORE component is used as part of the overall one-dimensional vessel representation. This is not expected to be an undue simplification because the Semiscale core is tall compared to its horizontal extent; moreover, use of the CORE component rather than the three-dimensional VESSEL component saves considerable computer time because, unlike all the TRAC one-dimensional components, the VESSEL component does not utilize the faster "two-step" numerics. As mentioned above, the upper head of the vessel has been removed for these experiments; in the TRAC model, the upper head is not modeled, but with the TEE components above the CORE component, the capped core support and guide tubes are explicitly modeled. The primary system drains are accomplished with a FILL component attached to the bottom of the TEE representing the lower plenum.

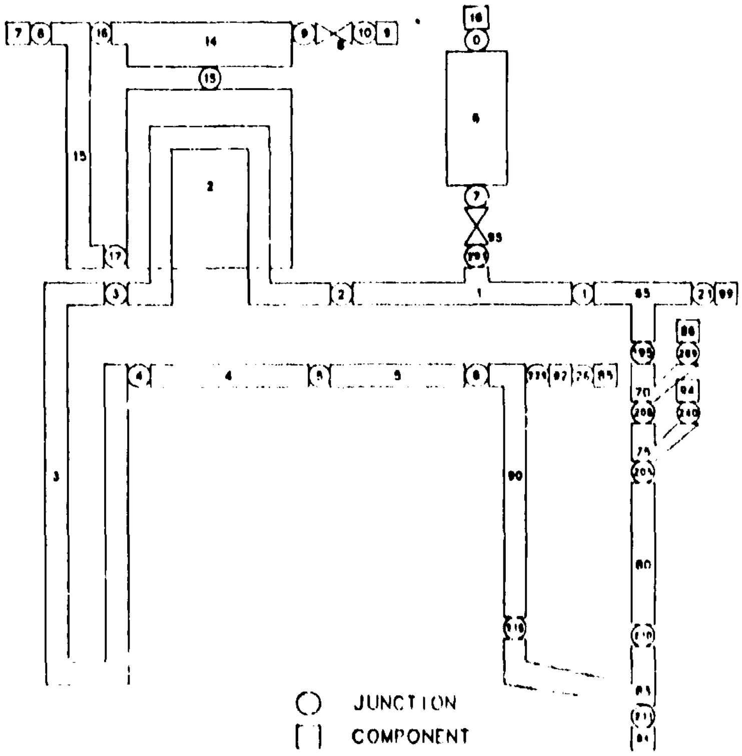

Fig. 1.
TRAC model for S-NC-2.

Note that the recirculation path, steam dome, and main steamline valve are modeled specifically for the steam-generator secondary. The steamline valve is represented by a VALVE component controlled by a trip and maintains a secondary pressure of 5.965 MPa ± 0.005 MPa. The feedwater is supplied by a FILL component that is controlled by the collapsed level in the steam generator; it maintains a level of about 9.4 m.

Although the Semiscale external-loop piping heaters are designed to offset the heat loss of the system, careful consideration of the data indicates that it is not adequate for these tests. For example, in the intact-loop pump suction, the heaters generally increase the fluid temperature for this set of experiments; further, the experiment data report for S-NC-2B (Ref. 1) mentions that the pump suction and cold-leg heaters were de-activated when boiling was observed in the steam-generator primary outlet. Accordingly, the TRAC model incorporates both the external heat losses and the external heaters to simulate more precisely the actual experiment. The heater power for each component is taken directly from the experiment data. The heat losses are not known in sufficient detail to distribute the heat losses accurately for each component in the model. Yet, the distribution and magnitudes of these losses are very important for a natural-circulation test; to distribute these losses properly, several steady-state TRAC runs were made varying the individual component heat losses until the liquid temperatures throughout the model closely matched that of the data.

As the intact-loop pump is replaced by an orificed spool piece, the TRAC model represents this section by a two-cell pipe with large additive friction (on the order of 10) at the second face. Because of the orifice geometry, the additive friction was determined by adjusting it over several runs to achieve the same flow rate given by the experimental data for the liquid-full system at steady state.

There is one change in the model for test S-NC-6 not shown in Fig. 1. The hot leg, component 1, is split into two TEE components; the one closer to the vessel is still attached to the pressurizer as shown, while the one connected to the steam generator is attached to a FILL that injects the correct amount of air (simulating nitrogen) at the appropriate times.

Because the natural-circulation flows and (especially the reflux flows) are of such a low magnitude, any spurious flows resulting from elevation errors could mask the true flows. Accordingly, a null transient where all wall heat transfer is de-activated was run before the TRAC prediction runs.

RESULTS

S-NC-2B

As shown in the pressure history for Test S-NC-2B (Fig. 2), the TRAC transient is run as close to the experiment as possible. This included executing the primary drains as indicated by the data and changing the core power level at the time and manner displayed by the data. The 30-kW core power segment extends from 0 to 15000 s. The 60-kW nominal core power segment encompasses 16000 to 26000 s, while the 100-kW case runs from 26500 s to the end of the test. In general, the TRAC prediction followed the test very well. For the 30-kW segment of the test, the TRAC prediction does not follow the data history as well as for the remainder of the test; this results from the inability to determine just when the system drains occur for this segment. In the remainder of the test, the timing of the drains is reasonably clear. It should also be noted that the dips in the data trace of the pressure correspond to dips in the secondary-side pressure and may result from the intermittent influx of cold feedwater.

Figures 3-5 display the extracted data of hot-leg mass flow as a function of system inventory for both TRAC and the experiment data. In general, the peak in mass flow occurs just before the voids are entrained beyond the tops of the tubes for the primary side in the

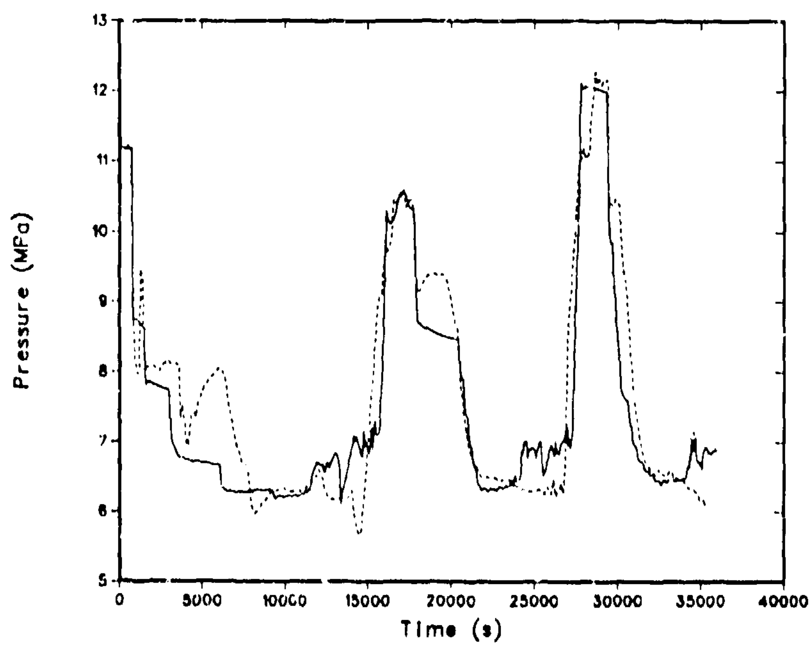

Fig. 2.
Pressure history for Test S-NC-2 (TRAC: solid curve, data: dashed curve).

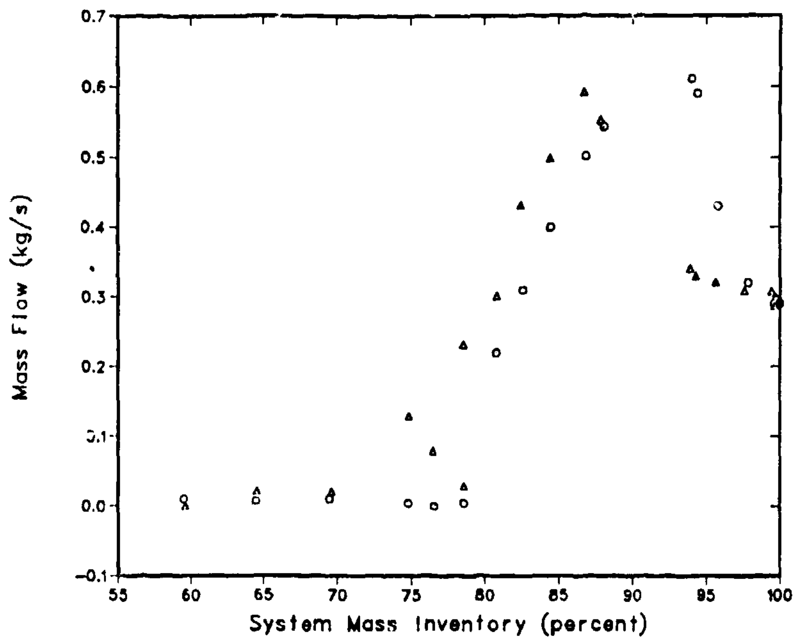

Fig. 3.
Natural-circulation mass flow as a function of primary system inventory for S-NC-2 with 30-kW core power (TRAC: circular symbols, data: triangular symbols).

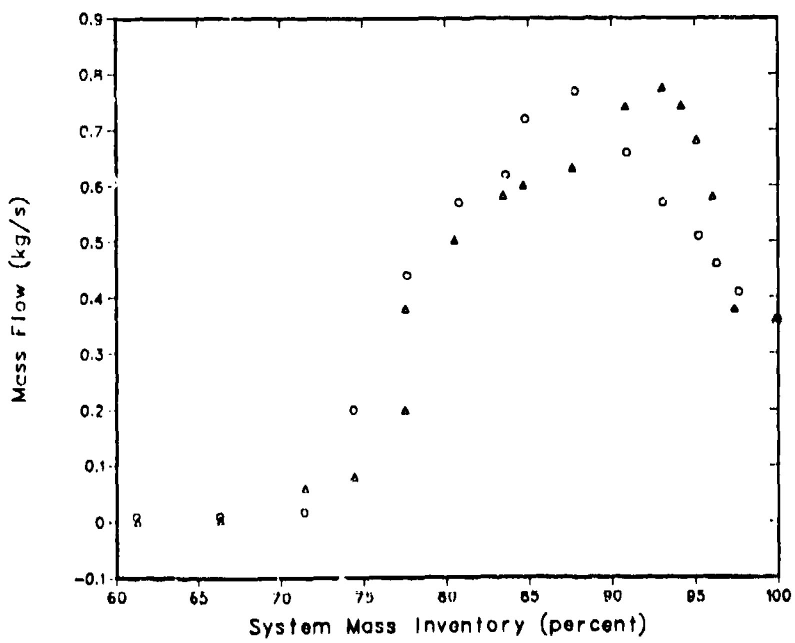

Fig. 4.
Natural-circulation mass flow as a function of primary system inventory for S-NC-2 with 60-kW core power (TRAC: circular symbol, data: triangular symbol).

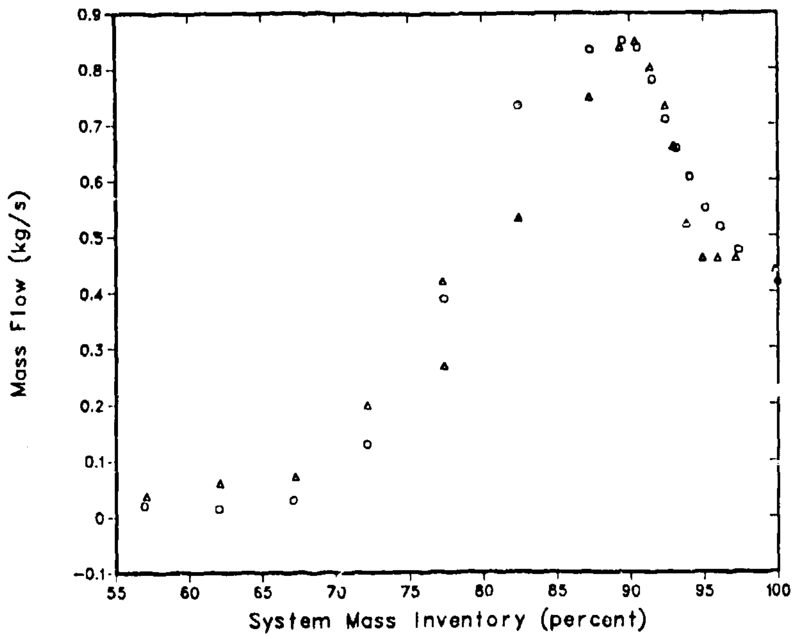

Fig. 5.
Natural-circulation mass flow as a function of primary system inventory for S-NC-2 with 100-kW core power (TRAC: circular symbol, data: triangular symbol).

steam generator. For the 30-kW case, as shown in Fig. 3, the peak in mass flow occurs for a higher system inventory than the data. However, the magnitude and subsequent behavior are very close to that of the data. From Fig. 4, the TRAC prediction of the mass flow peak occurs at a slightly smaller inventory than the data. Still, the general prediction compares very well with the data. In the high power case, 100 kW (Fig. 5), TRAC follows the data closely.

Primary pressure as a function of system inventory for the three power levels is shown in Figs. 6-8. In all three cases, TRAC does a reasonable job of predicting the system pressure above an inventory of 77%. Below a system inventory of 77%, in the reflux regime, the TRAC prediction of pressure is always high. This is a result of the PF1 wall-condensation heat-transfer model that underpredicts the heat transfer. As discussed below, when this model is replaced by the PF1/MOD1 model, the system pressure behaves properly. There is no provision in the experiment to measure the reflux rate.

In general, the Test S-NC-2B comparison shows that TRAC can predict well both single-phase and two-phase natural-circulation behavior.

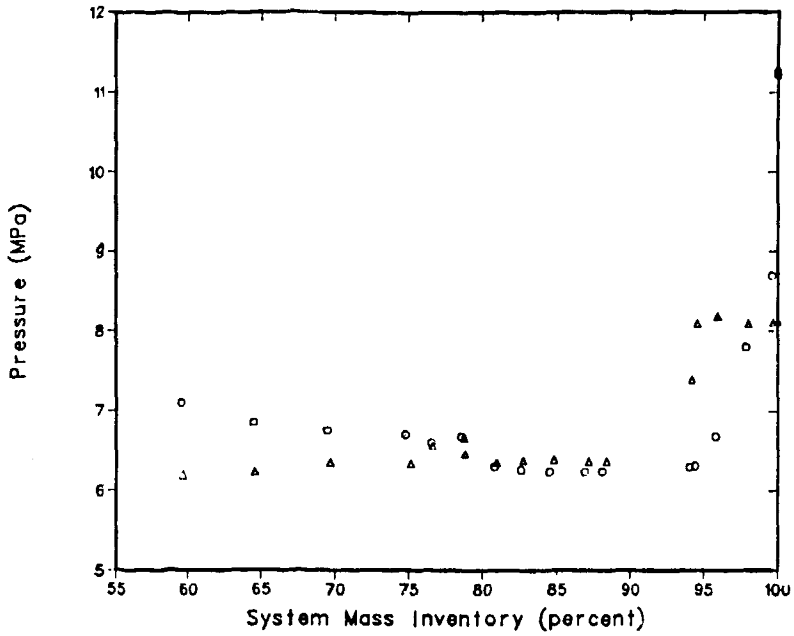

Fig. 6.
Primary pressure as a function of primary system inventory for S-NC-2 with 30-kW core power (TRAC: circular symbols, data: triangular symbols).

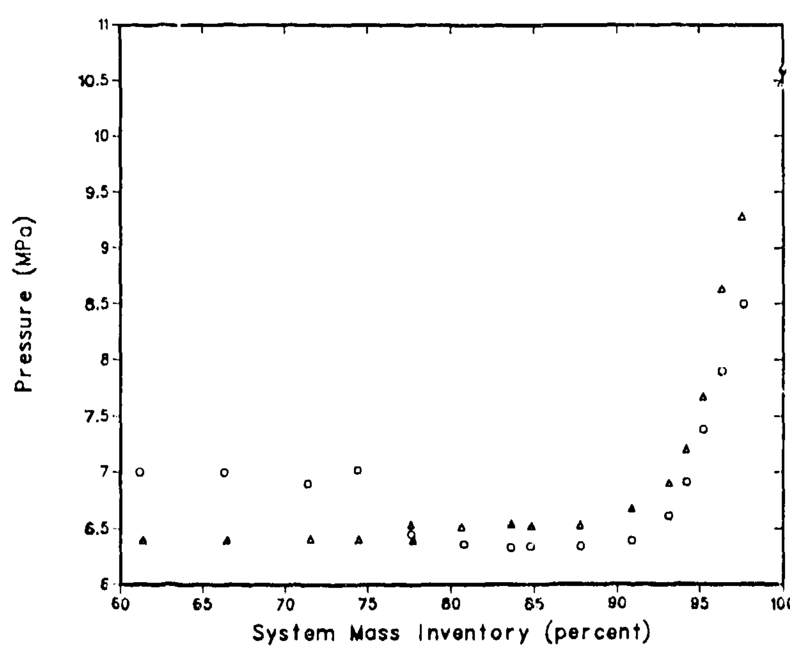

Fig. 7.
Primary pressure as a function of primary system inventory ror S-NC-2 with 60-kW core power (TRAC: circular symbols, data: triangular symbols).

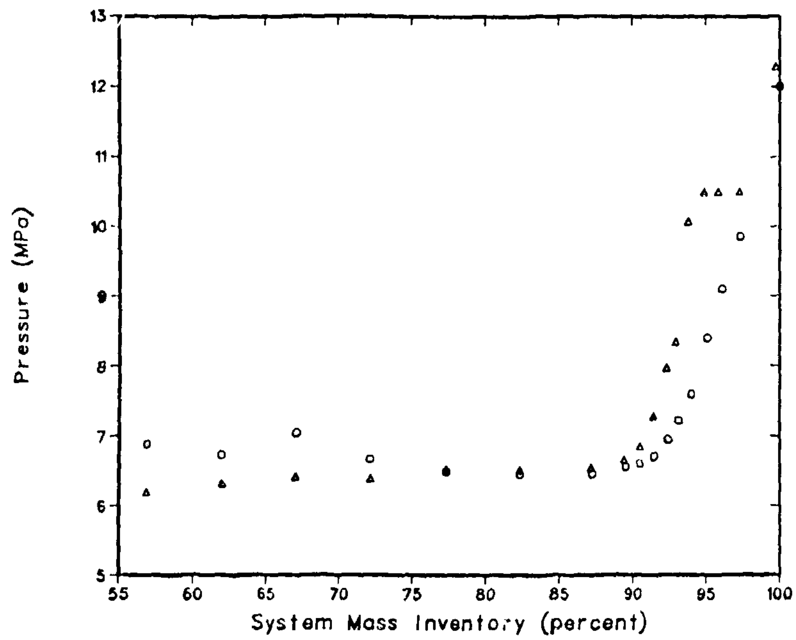

Fig. 8.
Primary pressure as a function of primary system inventory for S-NC-2 with 100-kW core power (TRAC: circular symbols, data: triangular symbols).

S-NC-6

As with S-NC-2B, the TRAC run with Test S-NC-6 is run as close to the experiment as possible. Figure 9 shows the pressure history for this test. Besides the TRAC prediction and the data, a third dotted curve is shown; this curve gives the TRAC prediction with the PF1 condensation heat-transfer model. As mentioned previously, this model underestimates the heat transfer and forces the primary temperature to increase during reflux to achieve the correct heat transfer. The TRAC predictions for this experiment are based on an update of the PF1 code that replaces this model with the PF1/MOD1 model. As shown by the solid curve in Fig. 9, the new wall-condensation heat-transfer model substantially improves the TRAC pressure prediction.

Figure 10 shows the reflux rate as a function of the injected nitrogen (air in the case of TRAC) for the upside of the steam generator. The circular and triangular symbols represent the individual reflux rates for TRAC and the data, respectively. The dashed line is the maximum vapor flow rate into the steam generator and thus the maximum reflux rate for the TRAC prediction; the chain-dot line is the maximum reflux rate for the data. For no nitrogen in the system, the TRAC prediction and the data are quite close, with the TRAC prediction being almost 10% lower. With

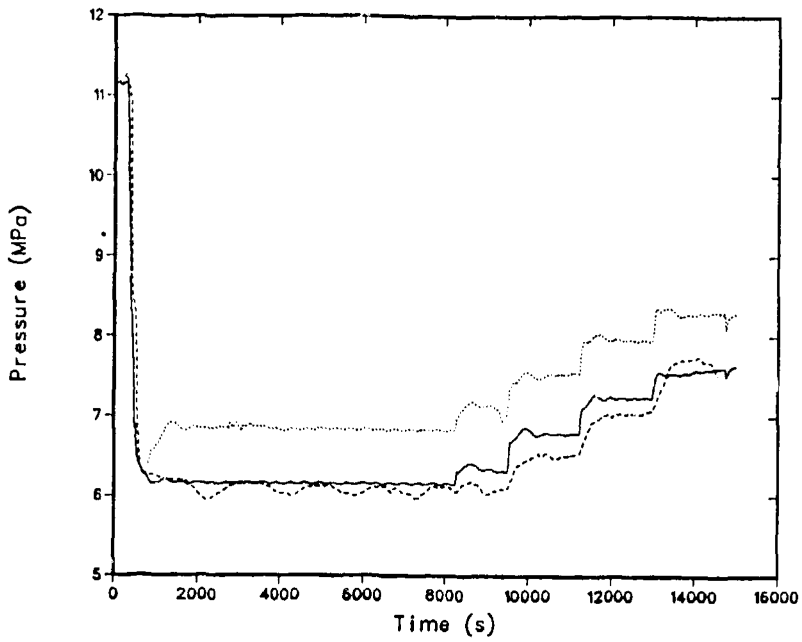

Fig. 9.
Pressure history for Test S-NC-6 (TRAC: solid curve, data: dashed curve, TRAC with underpredicting condensation heat-transfer model: dotted curve).

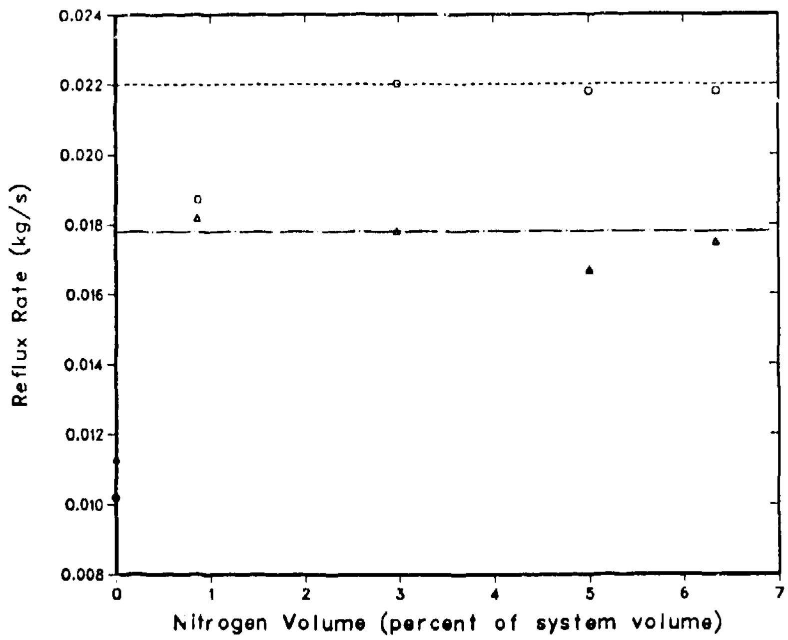

Fig. 10.
Reflux rate for the upside of the steam generator as a function of nitrogen volume (TRAC: circular symbols and dashed line, data: triangular symbols and chain-dot line).

nitrogen constituting 0.86% of the primary volume, the TRAC prediction and the data are even closer; The TRAC prediction is only 3% higher. For a nitrogen volume of 2.98% and higher, both the TRAC prediction and the data have reached the maximum reflux rate; the TRAC prediction is about 20% higher. There are no data for the downside of the steam generator, but the TRAC prediction is shown on Fig. 11. The dashed line represents the maximum reflux rate and the circular symbols are the individual reflux rate. Note that for no nitrogen in the system, just a bit more than half of the reflux flow occurs in the downside. This is in line with what was observed in the experiment.[4] As the amount of nitrogen increases, more reflux occurs in the upside. At 2.98% of nitrogen and above, all the reflux occurs in the upside.

Currently, we have no explanation for the higher TRAC prediction of the maximum reflux rate. One possible cause is that the TRAC model does not exactly model the manner in which the reflux liquid is removed from the system and then replaced by the make-up system. In the TRAC model, the refluxed liquid simply is allowed to run unimpeded through the hot leg into the core. Other contributors to the discrepancy include uncertainties in the heat losses and measurement error.

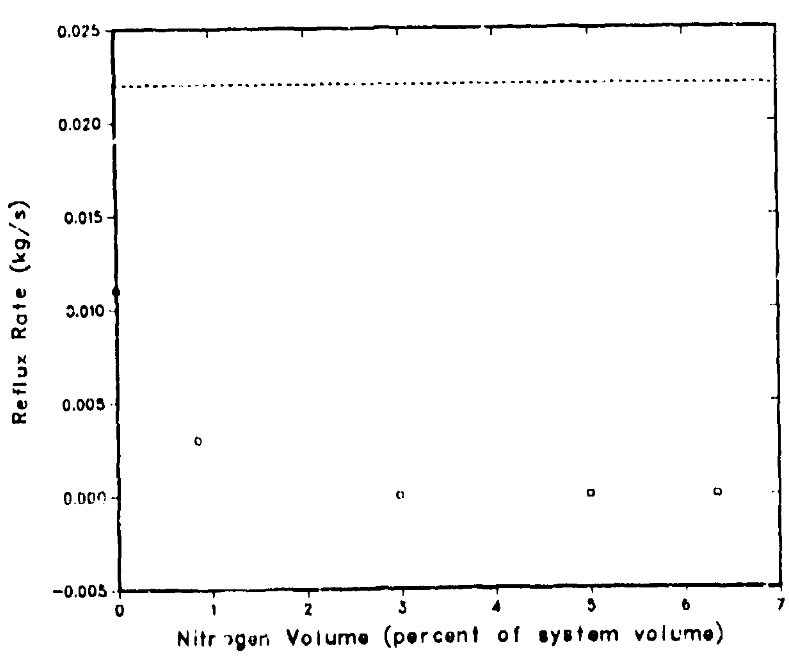

Fig. 11.
TRAC prediction of reflux rate as a function of nitrogen volume for the downside of the steam generator.

CONCLUSIONS

The results for Test S-NC-2B show that TRAC can ably predict single-phase and two-phase natural-circulation behavior in detail. From the S-NC-6 comparison, it is obvious that TRAC can model reflux behavior even though the input model may require some changes to account for the reflux meter for better simulation of this particular experiment.

REFERENCES

1. Thomas M. O'Connell, "Experiment Data Report for Semiscale MOD-2A Natural Circulation Tests S-NC-2B, S-NC-3, and S-NC-4B," EG&G Idaho, NUREG/CR-2454, EGG-2141, December 1981.
2. David Shimeck, private communication, August 17, 1982.
3. Thomas M. O'Connell, "Experiment Data Report for Semiscale MOD-2A Natural Circulation Tests S-NC-5 and S-NC-6," EG&G Idaho, NUREG/CR-2501, EGG-2162, January 1982.
4. Guy G. Loomis and Kunihisa Soda, "Results of the Semiscale MOD-2A Natural Circulation Experiments," EG&G Idaho, NUREG/CR-2335, EGG-2200, September 1982.